



## Environmental toxicity assesment on organic dyes using Typha Angustata

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### Abstract

Organic dyes are used in many industries like leathers, food, coloring, printing, cosmetics and paper making industries. The dye molecules are common water pollutants. Trace amount of dyes present in the dye effluent affect the environment. Typha Angustata Plant (sambu grass) is selected to identify the plant poisoning and non-poisoning organic dyes through adsorption method. The adsorption of organic dyes has been performed by various conditions such as concentration, contact time; temperature and pH are optimized to find out the maximum toxic effect of organic dyes on Typha Angustata Plant. The kinetics, thermodynamic and isotherms models are evaluated to find out the poisoning effects on Typha Angustata Plant.

**Keywords:** Adsorption; Environmental studies; Organic dyes; Typha Angustata Plant; Toxicity.

### 1. INTRODUCTION

Dyes are basically natural or synthetic organic compounds that can themselves to surfaces or fabrics to provide bright and lasting color. They are applied in various industries such as leather, textile, paper, rubber, cosmetics, plastics, pharmaceuticals and food industries. Most of them are complex organic molecules. It is resistant to many things such as the action of detergents (Chincholi *et al.* 2014; Yagub *et al.* 2014). Colored dye waste water is regarded as a direct result of the production of the dye. It is also as a consequence of its use in the textile and related industries. There are more than 10,000 commercial dyes are known with an annual production of over  $7 \times 10^5$  tones per year (Sen *et al.* 2011). It is estimated that 2% of the dyes are discharged in effluent from manufacturing operation, while 10% was discharged from textile and associated industries (Allen *et al.* 2004).

Discharge of these dyes into the water streams will affects the people who may use these effluents for living purposes such as washing, bathing and drinking (Sharma and Sobti, 2000). Some dyes can cause allergy, dermatitis, skin irritation, cancer and mutations in humans (Bhatnagar and Jain, 2005). Apart from that dyes also associated with environmental concern with

their absorption and reflection of sunlight entering the water, which will inhibit the growth of bacteria, limiting it to levels insufficient to biologically degrade impurities in the water (Mckay and Al Duri, 1987). Furthermore dye can also affect the aquatic plants as they reduce sunlight transmission through water. Therefore, the removal of such colored compounds from waste effluents becomes environmentally important because even a small amount dyes in water can be toxic and highly visible (Chiou *et al.* 2004).

Different physical-chemical processes have been applied for the treatment of colored wastewater. These include precipitation, flocculation, electro-kinetic, coagulation, electro-flotation, ion-exchange, membrane filtration, electro-chemical destruction, irradiation and ozonation. However, all these treatment methods are costly, suffering from many restrictions and cannot be utilized by small industries to treat the wide range of waste water (Indra *et al.* 2005).

Natural plant waste is widely used for water treatment process. The agricultural waste materials such as tea waste (Uddin *et al.* 2009), wheat straw (Zhang *et al.* 2011), grass waste (Hameed, 2009), jack fruit peel, palm shell activated carbon (Foo and Hameed, 2012), coir pith carbon, sugarcane stalks, neem leaf powder, saw dust (Itodo *et al.* 2012) and

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carrot stem powder were used for the removal of methylene blue and other dyes from waste water.

Adsorption is well-known equilibrium separation process and an effective method for water decontamination applications (Dabrowski, 2001). Adsorption has been found to be superior to other techniques for water re-use in terms of initial cost, flexibility and simplicity of design, ease of operation and insensitivity to toxic pollutants. Adsorption also does not result in the formation of harmful substances.

### Typha angustata as an adsorbent

*Typha angustata* (shown in Fig. 1) is a perennial plant and is an aquatic weed and is widely grown in waterlogged areas and is belongs to the family Typhaceae in the plant kingdom. *Typha angustata* is the most popular medicinal plant used for various medicinal properties and reported in many traditional literatures in India, as well as in China and Turkey.

The height is 1.5-2cm, and its leaf and stem are standing straightly. Its leaf is thick and has 5-12 mm thickness. Male and female flowers develop in the dense, complex spikes on the same vertical stem. The male flowers are reduced to a pair of stamens and hairs and wither once the pollen is shed, leaving a short and bare stem portion above the female inflorescence. The stem is joint less. The dense cluster of female flowers forms a cylindrical spike some 10 to as much as 40cm and 1 to 4 cm broad. Seeds are minute about 0.2 mm long and attached to a thin hair or stalk which effects wind dispersal (Poots and McKay, 1978).

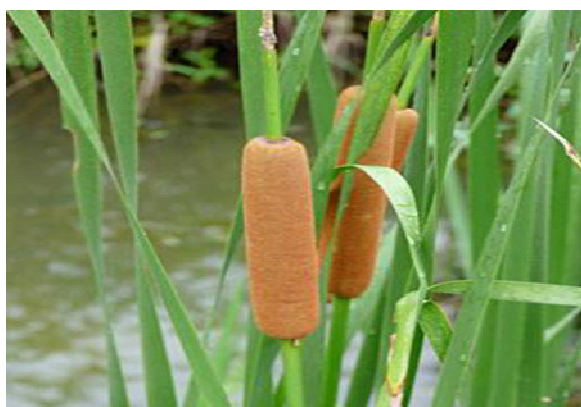


Fig. 1: *Typha angustata* (Sambu grass)

At present work *Typha angustata* raw material can be successfully employed as low cost alternative to the commercial adsorbents for the removal of Crystal Violet and Orange-G dye.

Table 1. Physical and Chemical properties of CV and OG

Dye	Chemical Formula	Molecular Formula	Maximum absorption ( $\lambda_{max}$ )	Make
Crystal Violet	$C_{25}H_{30}ClN_3$	408	591	Loba chemie pvt ltd
Orange -G	$C_{16}H_{10}N_2Na_2O_7S_2$	452.38	480	Loba chemie pvt ltd

## 2. EXPERIMENTAL

### 2.1 Materials and Methods

The dyes used in this study are Crystal Violet (Loba chemie) and Orange G. The physical and chemical properties of Crystal Violet and Orange G are listed in Table 1 and the structures are given in (Fig. 2 & 3).

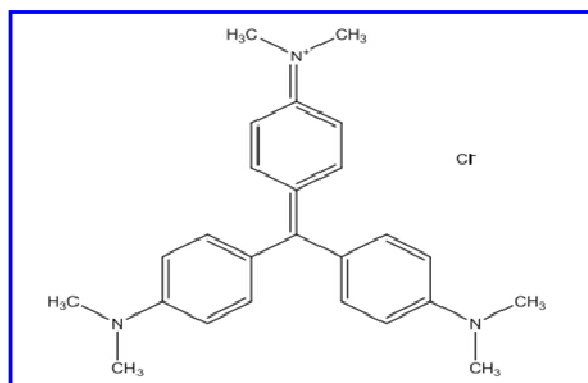


Fig. 2: Structure of Crystal Violet

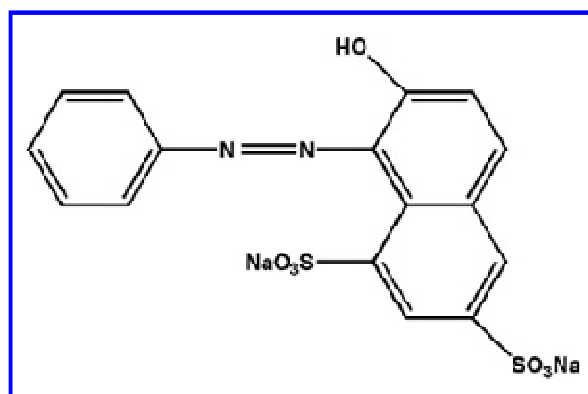


Fig. 3: Structure of Orange-G

### 2.2 TAP Powder preparation

*Typha angustata* plant without flower is collected. The plants are cut into small pieces and then dried in sunlight for one week. These small pieces are grained well to make a powder. Then the powder is

washed with repeated distilled water to remove the surface adhered materials and water soluble substance present in the powder. Finally the powder is dried in a hot air oven at 110°C.

### 2.3 Adsorption Experiment

The stock solution of 1000 mg/l is prepared by dissolving 1g of CV and OG in a standard measuring flask separately. The working solutions of desired concentration are prepared by successive dilution of stock solution. The dye concentration is analyzed by UV-Spectrophotometer (Perkin Elmer model lambda-25). The dried adsorbent (0.5g) is added with 50ml of CV and OG solution in 100ml conical flask separately. The mixture is stirred on magnetic stirrer (Remi-model-1MH) and the final concentration of the solution is measured spectrophotometrically.

The percentage removal of dye is calculated using the following equation

$$\% \text{ removal} = (C_o - C_e) / C_o \times 100$$

The amount of dye adsorbed per g of TAP powder is calculated from the following equation

$$Q_e = (C_o - C_e) V / W$$

Where,

- $C_o$  initial concentration of dye (mg/L)
- $C_e$  equilibrium concentration of dye (mg/L)
- $V$  Volume of the solution (L)
- $W$  mass of the adsorbent (g)

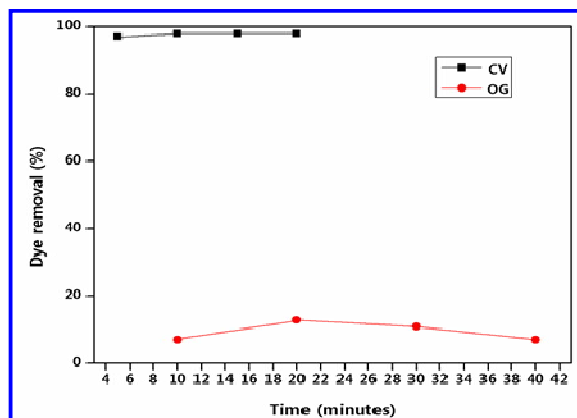
## 3. RESULT & DISSCUSSION

### 3.1 Adsorption Studies

#### 3.1.1 Adsorption of organic dyes on Typha Angstata plant

##### 3.1.1.1 Effect of contact time

The effect of contact time for the adsorption of CV and OG are carried out at room temperature. The percentage removal of dyes at room temperature as a function of time is shown in **Fig. 4**. Very rapid adsorption is observed within 10 min for CV whereas the removal of OG is 13% in 20 min. The rapid adsorption of CV is due to the interaction of cationic dye CV on the basic surface of the TAP powder. The poor adsorption of OG may be due to the less interaction between the anionic dyes on basic cellulosic surface. The adsorption of CV is rapid. This may be due to the strong active sites/ basic sites present in the TAP powder may attract the cationic CV (Eren and Acar, 2006).



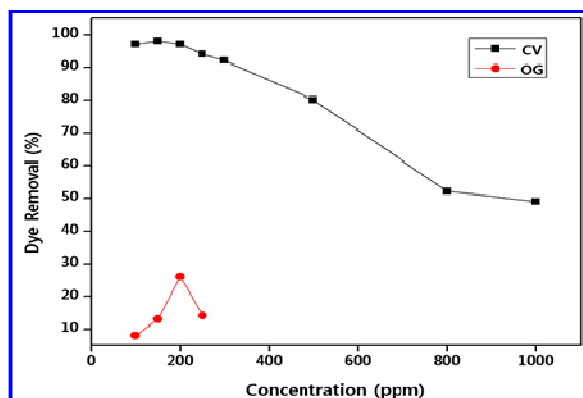
**Fig. 4: Effect of contact time for the uptake of CV and OG on TAP**

**CV: Concentration-100mg/l, adsorbent dosage-0.5g/50ml, temperature-30°C**

**OG: Concentration-100mg/l, adsorbent dosage-0.5g/50ml, temperature-30°C**

##### 3.1.1.2 Effect of concentration

The effect of dye concentration for the adsorption of CV and OG are shown in **Fig. 5**. Percentage adsorption of CV is decreased with increase of initial dye concentration from 97 % to 49 %. Contact time for the adsorption of CV is 10 min. The decreased of adsorption with increase of concentration may be due to the saturation of surface area and active sites available on TAP powder.



**Fig. 5: Effect of concentration for the uptake of CV and OG on TAP**

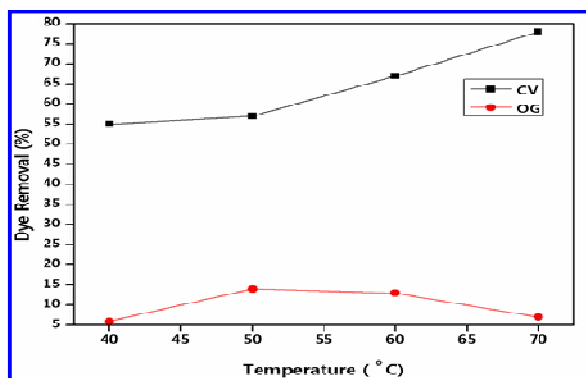
**CV: adsorbent dosage - 0.5g/50ml, time-10 min, temperature-30°C**

**OG: adsorbent dosage - 0.5g/50ml, time-20 min, temperature-30°C**

Percentage adsorption is increases with decreased of initial dye concentration and reaches the maximum and then decreases adsorption for OG on TAP powder (Senthilkumaar et al. 2006).

### 3.1.1.3 Effect of Temperature

The effects of temperature for the adsorption of dyes have been studied at 30-80°C are shown in Fig. 6. Percentage adsorption increases with increased of temperature for CV. The reason for increased in the adsorption of CV with increase of temperature is due to the strong interaction between CV and cellulosic surface of the adsorbent. When the temperature increased above 40°C, the absorption also increased, it is due to the activation of weak active sites in high temperature. Hence, adsorption increases with increased of temperature. But in case of OG, the adsorption increases with increased of temperature and further increased of temperature decreased to adsorption. This may be due to the repulsion of anionic OG and the basic surface of the TAP powder (Qadeer, 2007).



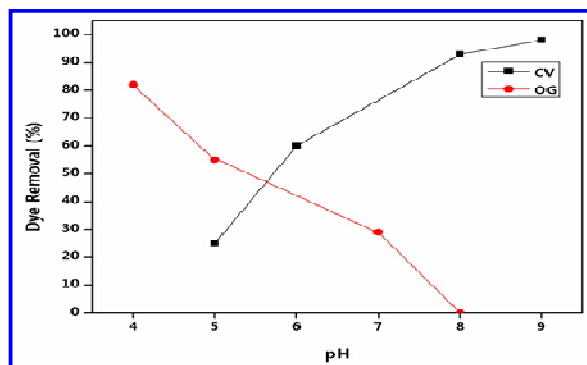
**Fig. 6: Effect of temperature for the uptake of CV and OG on TAP**

CV: Concentration-800mg/l, adsorbent dosage-0.5g/50ml, time-10 min

OG: Concentration-200mg/l, adsorbent dosage-0.5g/50ml, time-20 min

### 3.1.1.4 Effect of pH

The effect of pH of the solution on the adsorption of CV and OG is presented in Fig. 7. Experiments are performed with pH (4.0-9.0) for 50mL of dye solution and the adsorbent dose of 0.5 g. CV. Adsorption increases from 25% to 98% with an increase in pH, further there is no significant change at higher pH. At lower pH, adsorbent surface generates net positive charge due to higher concentration of  $H^+$  ions. As a result, there is an electrostatic repulsion between cationic CV molecules and adsorbent surface, which inhibits the CV removal. On the anionic dye, the maximum removal of the OG is decreased from 82% to 29% with increasing pH. Higher  $OH^-$  ions generate a net negative charge on the adsorbent surface. These results revealed that cationic and anionic dyes require basic and acidic medium respectively for maximum removal (Salleh et al. 2011).



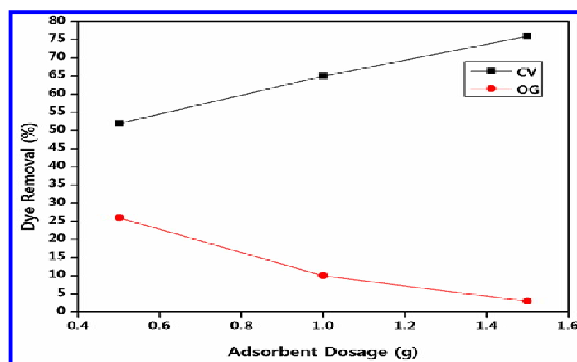
**Fig. 7: Effect of pH for the uptake of CV and OG on TAP**

CV: Concentration-800mg/l, adsorbent dosage-0.5g/50ml, time-10min, Temperature-30°C

OG: Concentration-200mg/l, adsorbent dosage-0.5g/50ml, time-20min, Temperature-30°C

### 3.1.1.5 Effect of adsorbent dosage

The effect of dosage for the adsorption of CV and OG are shown in Fig. 8, the percentage adsorption increases with increased of adsorbent dosage. By increasing the adsorbent dosage, the number of active sites as well as the surface area also increased. For CV the adsorption increased from 52 to 76% for the adsorbent dosage of 0.5 to 1.5g. OG adsorption decreased from 26 to 3% with increase of adsorbent dosage of 0.5 to 1.5g. In TAP, adsorbent surface carries basic sites, due to the presence of basic sites, the anionic dye adsorption decreases with increased of dosage (Salleh et al. 2011).



**Fig. 8: Effect of adsorbent dosage for the uptake of CV and OG on TAP**

CV: Concentration-800mg/l, pH-7, time-10 min

OG: Concentration-200mg/l, pH-6, time-20 min

## 3.2 Adsorption Kinetics

### 3.2.1 Pseudo- second order kinetics

The adsorption kinetics of CV and OG on TAP powder has been studied. The Pseudo second order equation is represented as follows:

$$t / Q_t = 1/K_2 Q_e^2 + 1/Q_e t$$

Where,

$K_2$  is the rate constant for pseudo-second order adsorption ( $\text{g m}^{-1} \text{min}^{-1}$ ).

$Q_e$  is the amount of dye adsorbed per unit mass of the adsorbent at equilibrium ( $\text{mg g}^{-1}$ ).

$Q_t$  is the amount of dye adsorbed per unit mass of the adsorbent at time  $t$  ( $\text{mg g}^{-1}$ ).

$t$  is time in minutes.

The plot of  $(t/Q_t)$  versus  $t$  gives straight line for the adsorption of CV and OG on TAP powder. The kinetic plot is shown in (Fig. 9 & 10). The linear regression coefficient ( $R^2$ ) values are higher than 0.99 indicating that the adsorption follows the pseudo-second order kinetics. The pseudo-second order kinetic data for the adsorption of CV and OG on TAP powder are given in Table 2.

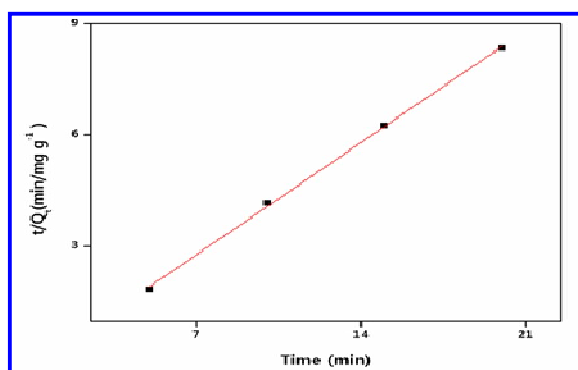


Fig. 9: Pseudo-second order kinetics plot for the adsorption of CV on TAP

Table 2. Pseudo-second order kinetics parameters for the adsorption of CV and OG on TAP

Adsorbent	Dye	$K_2$ ( $\text{s}^{-1}$ )	$R^2$
TA	CV	0.4305	0.9989
	OG	0.0719	0.9943

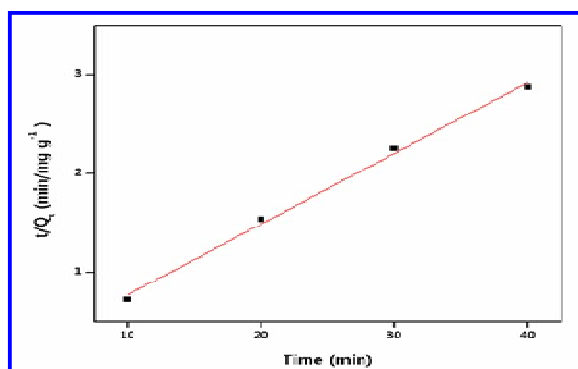


Fig. 10: Pseudo-second order kinetics plot for the adsorption of OG on TAP

### 3.3 Adsorption isotherm

#### 3.3.1 Langmuir adsorption isotherm

The adsorption capacity and interaction between adsorbent and adsorbate were described by adsorption isotherms. Langmuir and Freundlich adsorption isotherms are used to optimize the design of adsorption system. Adsorptions of CV and OG at different concentrations are studied and the data are given in Table 3.

A linear form of the Langmuir model may be written as

$$C_e / Q_e = (1/Q_{\max} K_L) + (C_e / Q_{\max})$$

Where,

$Q_e$  is the equilibrium concentration of dyes on the adsorbent ( $\text{mg g}^{-1}$ )

$C_e$  is the equilibrium concentration of dyes in solution ( $\text{mg L}^{-1}$ )

$Q_{\max}$  is the monolayer capacity of Adsorbent ( $\text{mg/g}$ )

$K_L$  is the Langmuir adsorption constant.

A plot of  $C_e/Q_e$  Vs  $C_e$  is a straight line with slope  $1/Q_{\max}$  and the intercept  $1/Q_{\max} K_L$  (Fig. 11 & 12). The correlation coefficient ( $R^2$ ) values are 0.9891 and 0.8449 for CV and OG respectively. The correlation coefficient ( $R^2$ ) value is very close to 1 for CV, indicated that the adsorption process follows the Langmuir adsorption isotherm.

Table 3. Langmuir parameters for the adsorption of CV and OG on TAP

Adsorbent	Dye	$Q_{\max}(\text{mg/g})$	$R^2$	$K_L$
TA	CV	47.8927	0.9891	0.3426
	OG	0.6486	0.9674	258.86

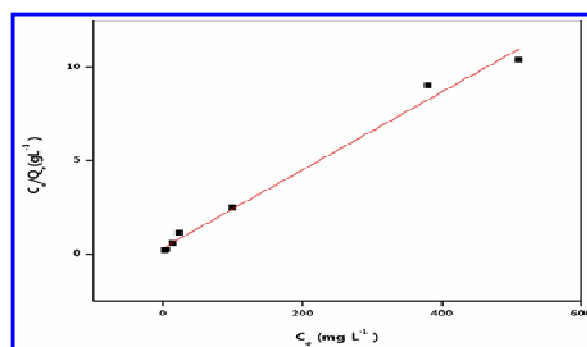


Fig. 11: Langmuir adsorption isotherms for the adsorption of OG on TAP

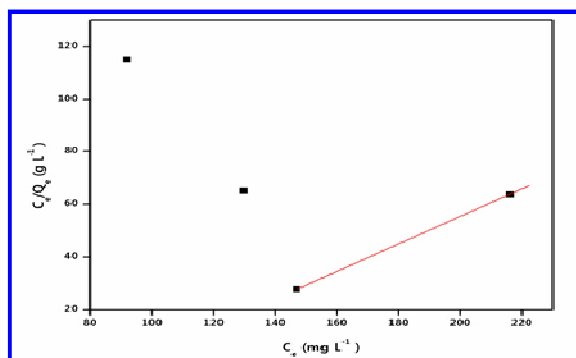


Fig. 12: Langmuir adsorption isotherms for the adsorption of CV on TAP

### 3.3.2 Freundlich isotherm

Freundlich isotherm model assumes the multilayer adsorption phenomenon. The adsorption studies are carried out at various concentrations at room temperature and the adsorption values are applied to the Freundlich equations to verify the adsorption isotherms of CV and OG on TAP powder.

Freundlich model in linear form is represented by the following equation,

$$\ln Q_e = \ln K_F + (1/n) \ln C_e$$

Where,

$K_F$  is the Freundlich constants  
 $n$  is the number of layer

The plot of  $\ln Q_e$  vs  $\ln C_e$  gave a straight line (Fig. 13 & 14) with the intercept  $\ln K_F$  and the slope  $1/n$ . The  $R^2$  values are 0.9177 and 0.8453 for CV and OG. The  $R^2$  value is low, when compared to Langmuir adsorption isotherm and it is indicated that the adsorption is well fitted through the Langmuir adsorption isotherm. The result obtained Langmuir and Freundlich adsorption isotherms are given in Table 4.

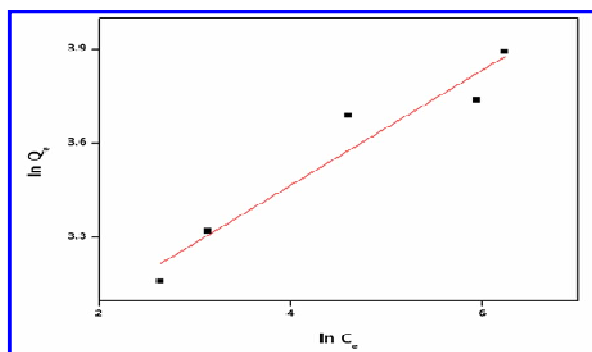


Fig. 13: Freundlich adsorption isotherms for the adsorption of CV on TAP

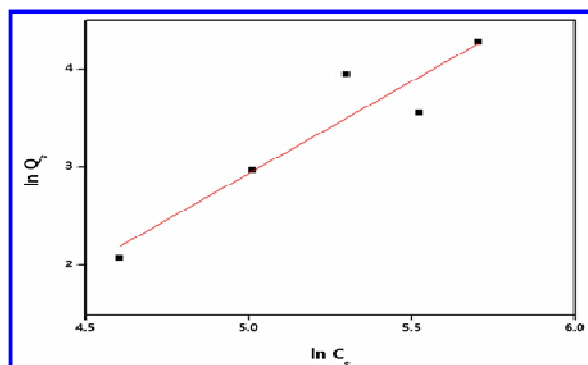


Fig. 14: Freundlich adsorption isotherms for the adsorption of OG on TAP

Table 4. Freundlich adsorption isotherm parameters

Adsorbent	Dye	N	$R^2$	$K_F$
Typha	CV	5.4495	0.9177	15.3567
Angustata	OG	0.5310	0.8453	0.00153

### 3.4 Thermodynamic study

Thermodynamic studies were done to elaborate the thermodynamic parameters. Experiments were carried out in the temperature ranges (30 - 70 °C) keeping all the parameters constant. Enthalpy ( $H^0$ ), entropy ( $S^0$ ) and change in Gibb's free energy ( $G^0$ ) were calculated for both the dyes by using Van't Hoff equation

$$K_D = q_e/C_e \quad (1)$$

$$\Delta G = -RT \ln K_D \quad (2)$$

$$\ln K_D = (\Delta S / R) - (\Delta H / RT) \quad (3)$$

From the equations eq.2 and eq.3,

$$\Delta G = \Delta H - T\Delta S \quad (4)$$

Where,

$K_D$  is the distribution coefficient of the adsorbate  
 $q_e$  is the equilibrium dye concentration on adsorbent ( $\text{mg g}^{-1}$ )  
 $C_e$  is the equilibrium dye concentration in the solution ( $\text{mg L}^{-1}$ )  
 $R$  is the universal gas constant ( $8.314 \text{ J/mol K}$ )  
 $T$  is the temperature (K).

$\Delta H^0$  and  $\Delta S^0$  parameters can be calculated from the slope and intercept of the plot  $\ln K_D$  vs.  $1/T$ , respectively (Fig.15 & 16). Results are summarized in Table.  $\Delta G^0$  values at the temperatures of 30°C – 70°C (303 K - 333 K) are negative Table 5. This indicated



that the process is feasible adsorption process and spontaneous.

The enthalpy ( $\Delta H^\circ$ ) values are greater than 40 KJ/mol indicated that the adsorption of dye over TAP powder is chemisorption. The positive value of enthalpy indicated that the adsorption process is endothermic. Moreover, the positive value of  $\Delta S^\circ$  indicated that the degrees of freedom increased at the solid-liquid interface during the adsorption.

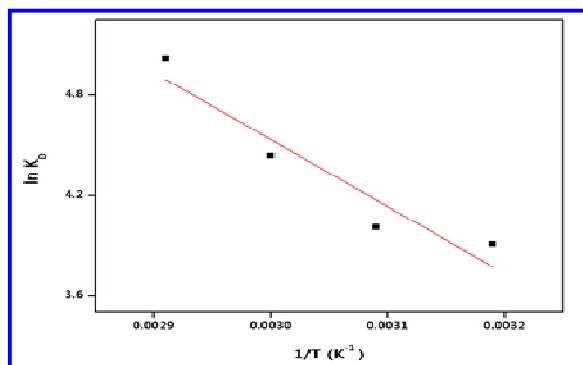


Fig. 15: Thermodynamic parameters plot for the adsorption of CV on TAP

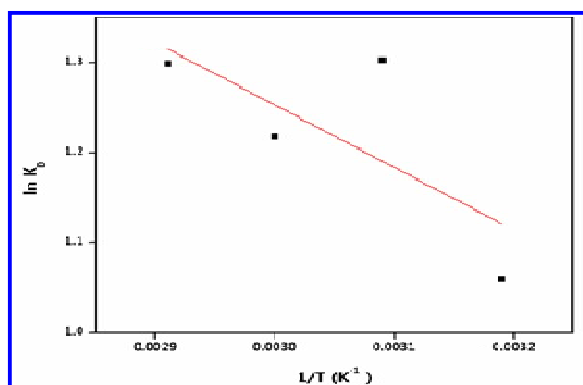


Fig. 16: Thermodynamic parameter plot for the adsorption of OG on TAP

Table 5. Thermodynamic parameters for the adsorption of CV and OG on TAP

Adsorbent	Dye	Temperature	$\Delta G^\circ$ (KJ/mol)	$\Delta H^\circ$ (KJ/mol)	$\Delta S^\circ$ (KJ/mol)
TA	C V	313	-9.7592	-41.309	0.1376
		323	-11.1352		
		333	-12.5112		
		343	-13.8872		
	O G	313	-2.9077	-5.7655	0.0270
		323	-3.1848		
		333	-3.4659		
		343	-3.7390		

## 4. CONCLUSION

The dye effluent has many organic dyes, these organic dyes polluting water, soil, plant and animal etc. The plant poisoning and soil polluting organic dyes identifications are reported in the literature, however, plant poisoning nature of organic dyes on TAP powder. In the present investigation, the adsorption of CV and OG has been studied on TAP to evaluate their toxic effect on plant. The following experimental conditions are optimized to attain maximum adsorption of CV and OG are given below:

- The effect of contact time has been optimized to find out the equilibrium adsorption of CV and OG on TAP. Very rapid adsorption is observed within 10 min for CV whereas the removal of OG is 13% in 20 min.
- The effect of concentration of dye has been optimized to find out the equilibrium adsorption of CV and OG on TAP. It is observed that percentage adsorption of CV decreases with increased of initial dye concentration from 97% to 49% respectively. Percentage adsorption is increases with increased of initial dye concentration and reaches the maximum and then decreases adsorption for OG on TAP powder.
- Temperature effect for the adsorption of CV and OG on TAP has been optimized to find out percentage adsorption increases with increased of temperature for CV. But in case of OG, the adsorption increases with increased of temperature and further increased of temperature decreases the adsorption.
- Adsorption increases from 25% to 98% with increased of pH, further there is no significant change at higher pH. On the anionic dye, the maximum removal of the OG decreases from 82% to 29% with increased of pH.
- The effect of adsorbent dosage variation shows that the adsorption increases from 52 to 76% with increased of adsorbent dosage for CV. But the adsorption decreases from 26 to 3% with increased of adsorbent dosage for OG.
- The adsorption on TAP powder follows pseudo-second order kinetics for CV and OG and obeys Langmuir adsorption isotherm only on CV.
- The thermodynamic study proved that the adsorption of CV is chemisorption and OG is physisorption on TAP.
- Thus this adsorption study proved that CV has more affinity on TAP powder than OG. Hence it rapidly toxic to plant than OG.

## REFERENCES

- Allen, S. J., McKay, G. and Porter, J. F., Adsorption isotherm models for basic dye adsorption by peat in single and binary component systems, *J. Colloid Interf. Sci.(JCIS)*, **280**, 322-333(2004).  
[doi:10.1016/j.jcis.2004.08.078](https://doi.org/10.1016/j.jcis.2004.08.078)
- Bhatnagar, A. and Jain, A. K., A comparative adsorption study with different industrial wastes as adsorbents for the removal of cationic dyes from water, *J. Colloid Interf. Sci.(JCIS)*, **281**, 49-55(2005).  
[doi:10.1016/j.jcis.2004.08.076](https://doi.org/10.1016/j.jcis.2004.08.076)
- Chincholi, M., Sagwekar, P., Nagaria, C., Kulkarni, S. and Dhokpande S., Removal of dye by adsorption on various adsorbents: a review, *Int. J. Sci. Eng. Technol. Res.(IJSETR)*, 3(4), 835-840(2014).
- Chiou, M. S., Ho, P. Y. and Li H. Y., Adsorption of anionic dyes in acid solutions using chemically cross-linked chitosan beads, *J. Dyes Pig.(JDP)*, **60**, 69-84(2004).
- Dabrowski, Adsorption from theory to practice, *Advanced Collid Interfacial Sci.(ACIS)*, **93**, 135-224(2001).
- Eren, Z. and Acar, F. N., Adsorption of Reactive Black 5 from an aqueous solution: equilibrium and kinetic studies, *Desalination*, **194**, 01-10(2006).
- Foo, K. Y. and Hameed, B. H., Dynamic adsorption behavior of methylene blue onto oil palm shell granular activated carbon prepared by microwave heating, *Chem Eng J.(CEJ)*, **203**, 81-87(2012).
- Hameed, B. H., Grass Waste: A novel sorbent for the removal of basic dye from aqueous solution, *J. Hazard. Mater.(JHM)*, **166**, 233- 238(2009).
- Indra, D. M., Vimal, C. S., Nitin, K. A. and Indra, M. M., Adsorptive removal of malachite green dye from aqueous solution by bagasse fly ash and activated carbon-kinetic study and equilibrium isotherm analyses, *Colloids Surf.(CS)*, **264**, 17-28(2005).
- Itodo, H. U. and Itodo, A. U., Surface coverage and adsorption study of dye uptake by derived Acid and Base treated mango seed shells, *J. Chem. Pharm. Res.(JCPR)*, **2**, 673- 683(2012).
- McKay, G. and Al Duri, B., Simplified model for the equilibrium adsorption of dyes from mixtures using activated carbon, *Chem. Eng. Process.(CEP)*, **22**, 145-156(1987).
- Poots, V. J. P., McKay, G. and Healy, J. J., Removal of basic dye from effluent using wood as an adsorbent, *J. Water. Pollut.(JWP)*, **50**, 926-936( 1978).
- Qadeer, R., Adsorption behavior of ruthenium ions on activated charcoal from nirtic acid medium, *Colloids Surf. A: Physicochem. Eng. Aspects.(CSAPEA)*, **293**, 217-223(2007).
- Salleh, M. A. M., Sulaiman, O., Mahmoud, D. K., Karim, W. A. W. A. and Idris, A., Cationic and anionic dye adsorption by agricultural solid wastes: A comprehensive review, *Desalination*, **280**, 01-13(2011).
- Sen, T. K., Afroze, S. and Ang, H., Equilibrium, kinetics and mechanism of removal of methylene blue from aqueous solution by adsorption onto pine cone biomass of Pinusradiata, *Water Air Soil Pollut.(WASP)*, **218**, 499-515(2011).
- Senthilkumar, S., Kalaamani, P. and Subburaam, C. V., Liquid phase adsorption of crystal violet onto activated carbons derived from male flowers of coconut, *J. Hazard. Mater.(JHM)*, **136**, 800-808(2006).
- Sharma, M. K. and Sobti, R. C., Rec effect of certain textile dyes in Bacillus subtilis, *Res. Gennet. Toxicol. Environ. Mutagen.(RGTEM)*, **465**, 27-38(2000).
- Uddin, M. T., Islam, M. A., Mahmud, S. and Rukanuzzaman, M., Adsorptive removal of methylene blue by tea waste, *J. Hazard. Mater.(JHM)*, **164**, 53- 60(2009).
- Yagub, M. T., Sen, T. K., Afroze, S. and Ang, H. M., Dye and its removal from aqueous solution by adsorption: A review, *Adv. Colloid Interfac.(ACI)*, **209**, 172-184 (2014).
- Zhang, W., Yan, H., Jiang, Z., Dong, L., Kan, X., Yang, H., Li, A. and Chang, R., Removal of dyes from aqueous solutions by straw based adsorbents, *Chem. Eng J.(CEJ)*, **168**, 1120-1127(2011).